THE AXAF ASPECT CAMERA SIMULATOR

M. Karovska

Harvard-Smithsonian Center for Astrophysics

Cambridge, MA 02138, USA, Email: karovska@cfa.harvard.edu

1. INTRODUCTION

I will describe a simulator of the optical assembly of the Advanced X-ray Astrophysics Facility (AXAF) Aspect Camera and the Fiducial Transfer System. The simulator produces realistic PSFs of stellar sources and fiducial lights which are used for modeling and verification of the "as build" system and in the centroid determination procedure - a crucial element in the aspect pipeline for deriving the post-facto aspect solution.

The AXAF aspect determination system (Birkinshaw and Karovska 1995) includes the following major subsystems:

(1) the aspect camera assembly (ACA), (Fig. 1),

(2) the fiducial light assembly (FLA), (Fig. 2), and

(3) the fiducial transfer system (FTS), (Fig. 2), including the fiducial transfer mirror (FTM) (Fig. 3).

2. GROUND ASPECT DETERMINATION SYSTEM

Up to eight images (normally five guide stars and three fiducial lights) are tracked by the aspect camera, and astrometry of these provides a history of the celestial pointing coordinates and roll angle for each X-ray observation.

The post-facto aspect solution is calculated using the the Ground Aspect Determination System (GADS) pipeline (Karovska et al 1996). The GADS pipeline (Fig. 4) produces an aspect solution in celestial coordinates, to support both image reconstruction (with error less than 0.5 arcsecond) and celestial location for X-ray data (with error less than 1 arcsecond).

3. CENTROID DETERMINATION

A crucial step in deriving the post-facto aspect solution is determining the centroids of each star or fiducial light image (performed in “Process ACA data” step in the aspect pipeline). To allow centroiding, the optics of the aspect camera telescope (ACT) is deliberately defocused. The diffraction limited image of the focused telescope of approximately 1 arcsecond in the visible, is smaller then the CCD pixel scale of 5 arcsec per pixel. The FWHM of the ACT defocused image of a star is about 9 arcsec, well spread out relative to the CCD scale.

The GADS pipeline uses two methods for deriving the centroids of PSF images:

- First moment centroiding method based on a flux-weighted moment calculations,

- PSF-fitting method which uses optimal model PSFs to calculate centroids and fluxes for each star and fiducial light image.

4. MODEL PSFs

The optimal model PSF for each image is obtained by interpolating from a database of model PSFs. The database contains two matrices of model PSFs for various positions on the CCD, one for the stellar PSFs, another for the fiducial lights. The fiducial lights PSFs are monochromatic, calibrated at one wavelength (635 nm), while for stars we add a third dimension in the matrix - star colors, to account for optical color effects on the PSFs. These model PSFs are defined on a pixel grid that is finer than that of the aspect camera itself, and are calculated using the parameters of the optical system as inputs into a simulator of the optical system. Each model PSF is sampled on a sub-CCD pixel scale grid (e.g. 12 x 12 sub-CCD pixels, each sub-CCD pixel scale of 0.4 arcseconds).

5. ASPECT OPTICS SIMULATOR

We developed models of the AXAF aspect determination optics system using the Modeling and Analysis of Controlled Optical Systems (MACOS) software package (D. Redding; Breault Research). MACOS subroutine package (SMACOS) allowed its integration with other codes in the aspect optics simulator software.

The aspect optics simulator consists of two components:

1. Component generating MACOS raytrace models of the optics of the ACT, FTM, FLA, and the FTS.
2. Component generating model PSFs for different stellar spectral types using the aspect camera optical assembly (ACA) normalized spectral response (Fig. 5).

In Fig. 6-13 I show several examples of results obtained using MACOS and the Aspect Optics Simulator, including simulated on- and off-axis aspect camera images on CCD and sub-CCD pixel scale.

Acknowledgements

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REFERENCES

Birkinshaw, M., Karovska, M. 1995, AXAF News,No. 3.

Karovska, M. , Aldcroft, T, Cameron, R., DePonte, J., and Birkinshaw, M. 1996, ADASS VI, p. 488.

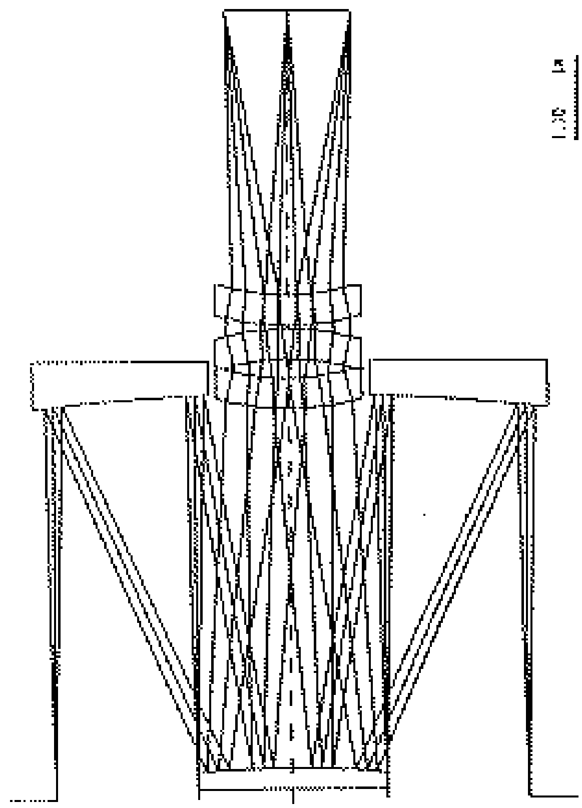


Fig. 1.— The principal component of the AXAF aspect camera is a 0.11 m diameter Ritchey-Chrétien telescope. It consists of a primary mirror, secondary mirror and a 3-element refractive corrector. The telescope images about 2 square degrees of sky into one of two red-sensitive 1024 x 1024 CCDs.

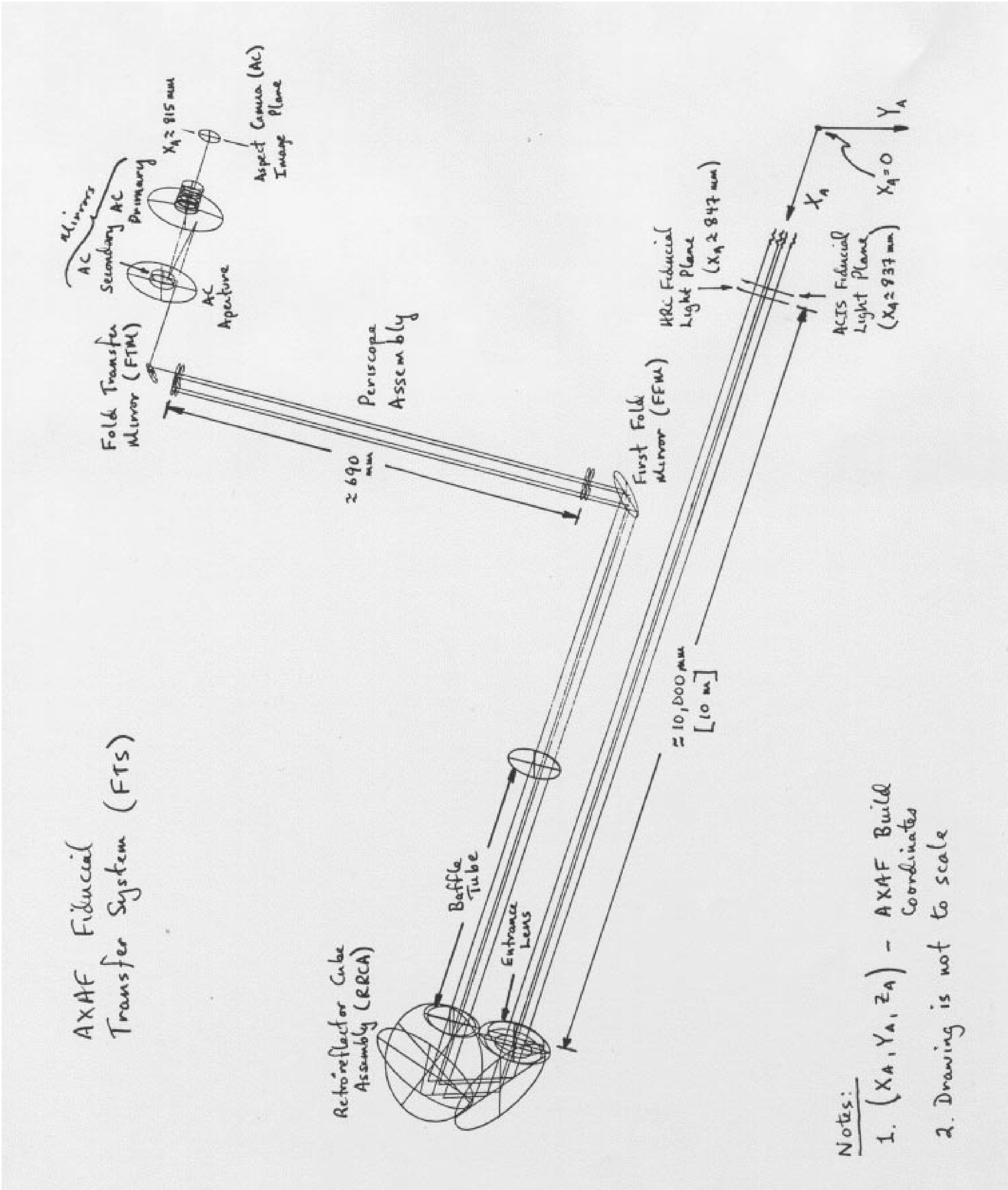


Fig. 2.— In addition to observing the optical sky directly, the aspect camera telescope also views the fiducial lights arranged around an X-ray detector. These lights are imaged via the fiducial transfer system consisting of a retroreflector/collimator and periscope, and the fiducial transfer mirror.

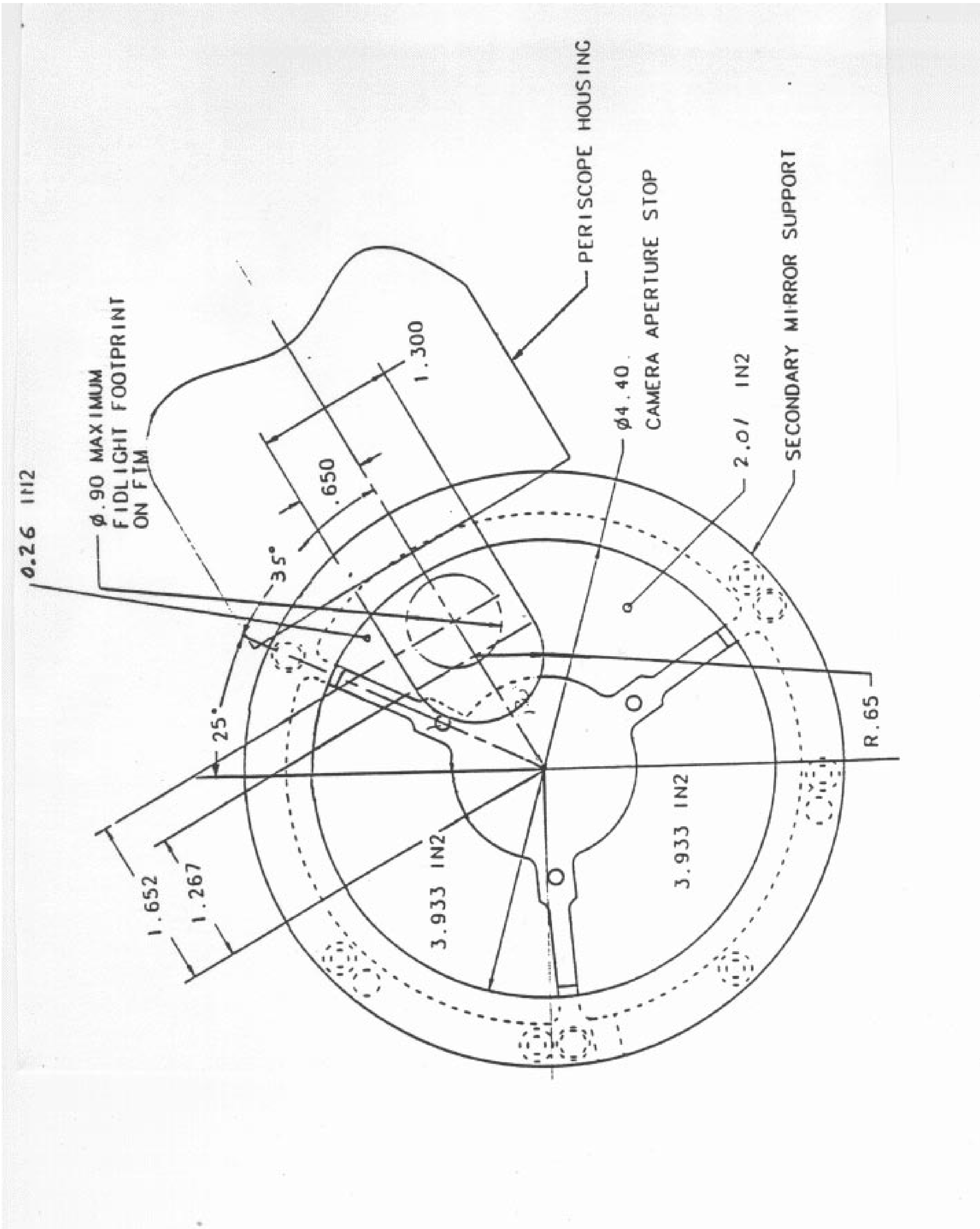
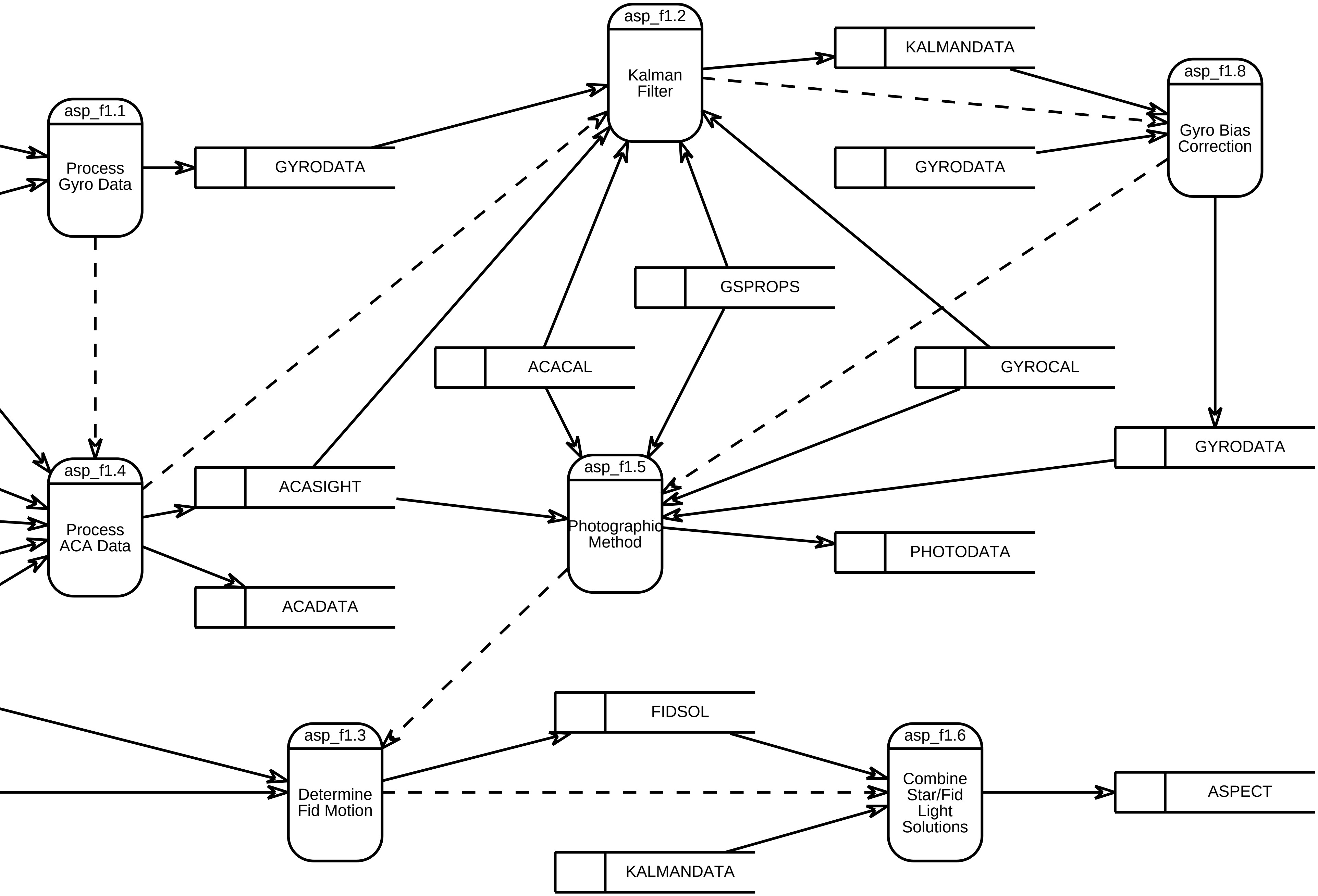


Fig. 3.— The Secondary Mirror Support and the FTM



asp_f1.1
Process Gyro Data
GYRODATA
asp_f1.2
Kalman Filter
KALMANDATA
asp_f1.8
Gyro Bias Correction
GYRODATA
GSPROPS
ACACAL
GYROCAL
GYRODATA
asp_f1.4
Process ACA Data
ACASIGHT
ACADATA
asp_f1.5
Photographic Method
PHOTODATA
FIDSOL
asp_f1.3
Determine Fid Motion
asp_f1.6
Combine Star/Fid Light Solutions
ASPECT
KALMANDATA

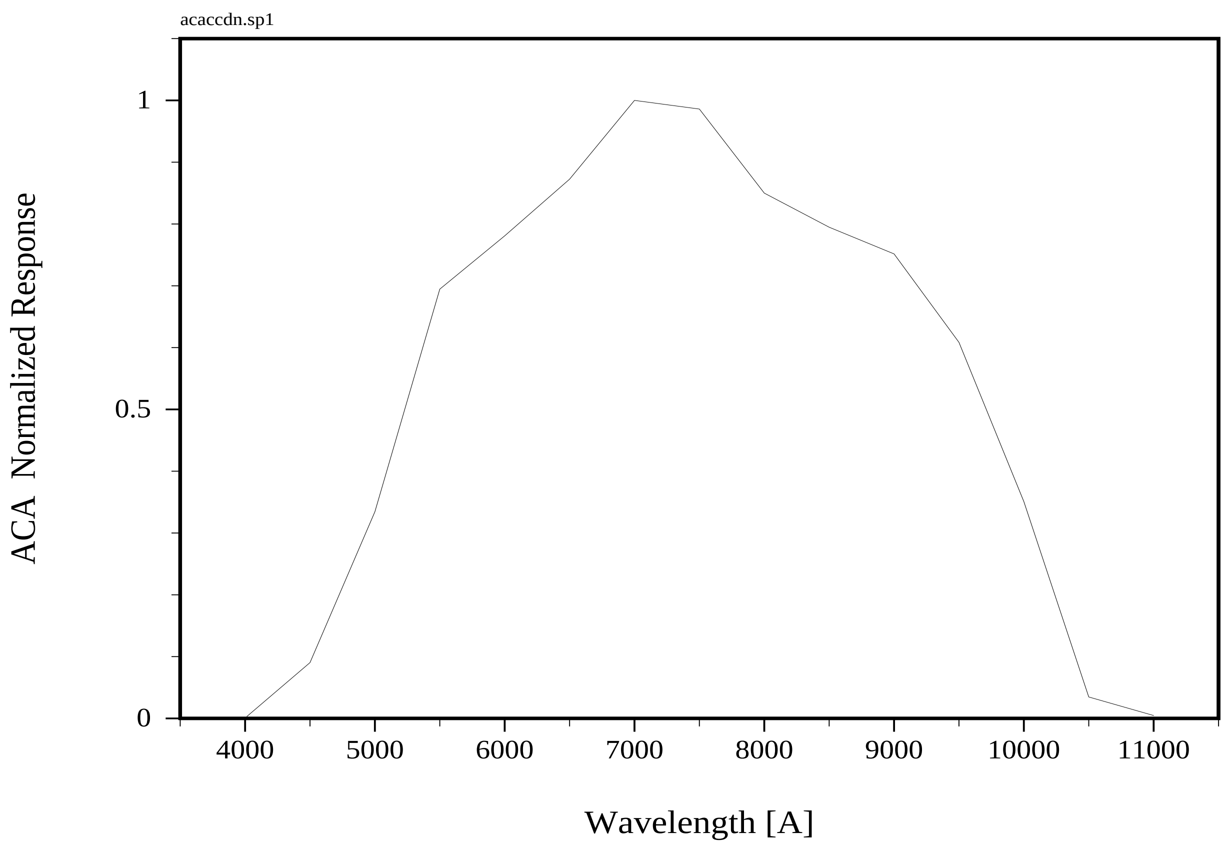


Fig. 5.— ACA Normalized Response

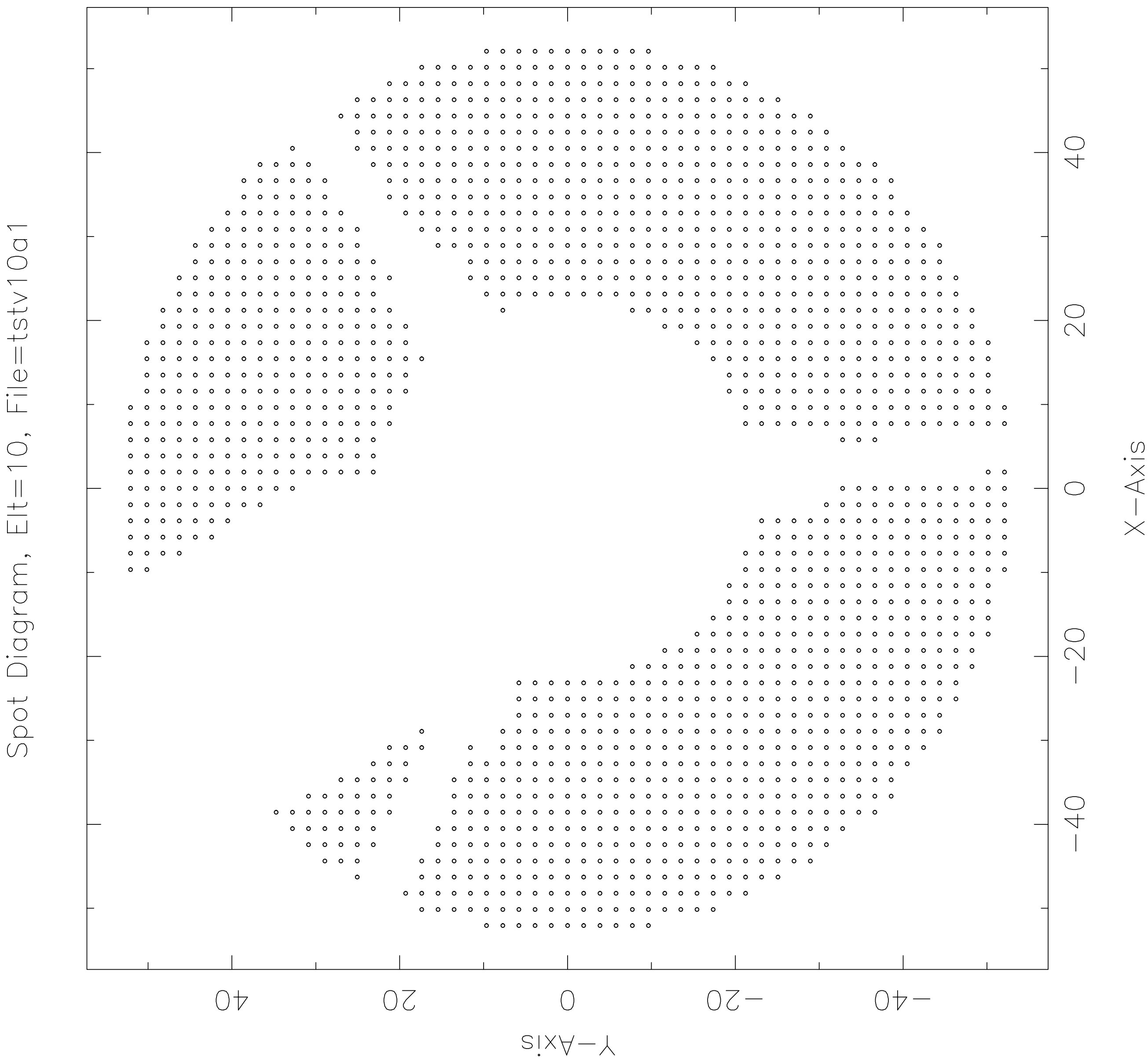


Fig. 6.— MACOS Spot Diagram of the aspect camera assembly with the three spiders, secondary mirror, and the FTM viewed from the back.

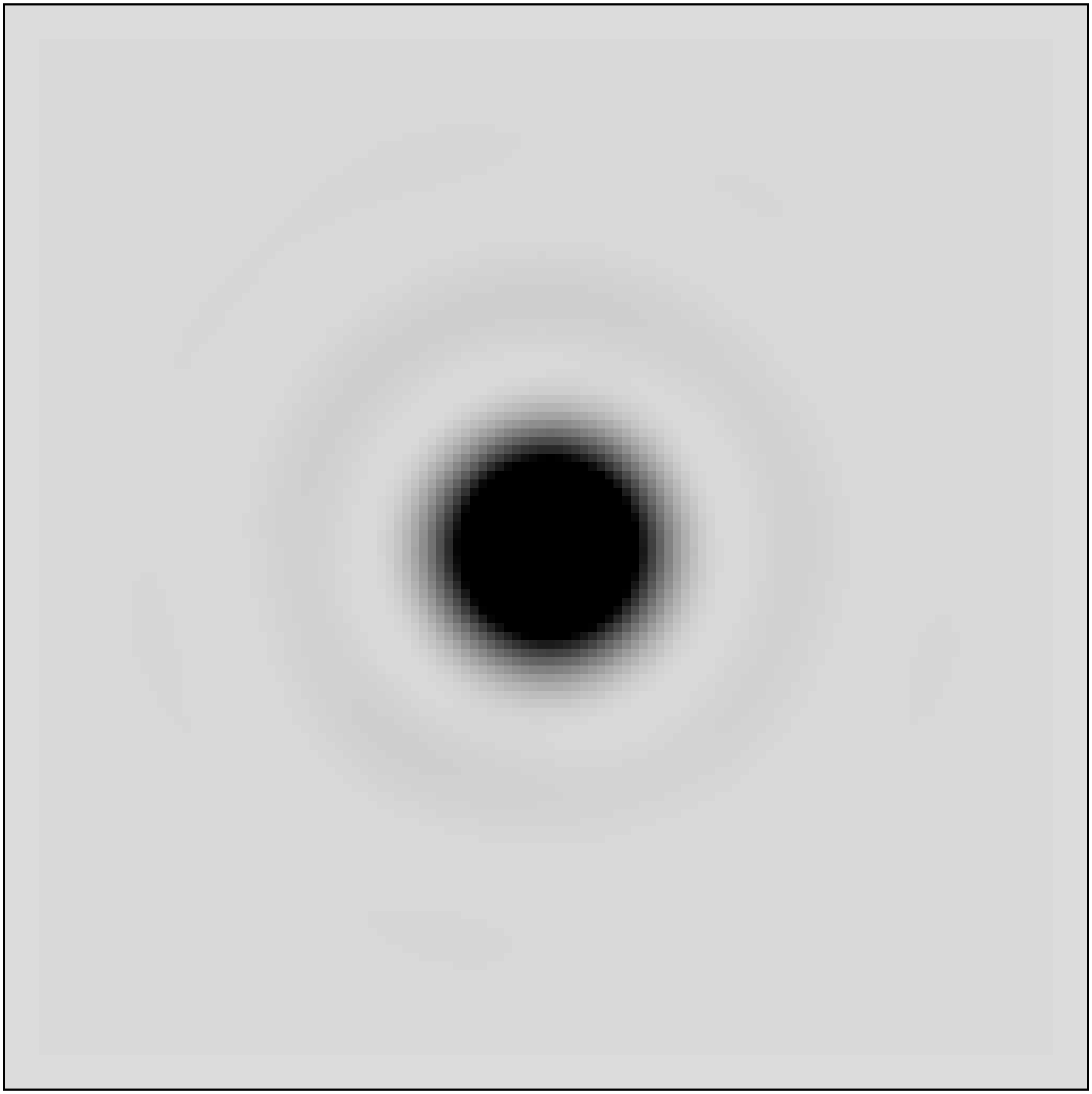


Fig. 7.— MACOS image of an on-axis fiducial light at 0.08 CCD-pixel scale

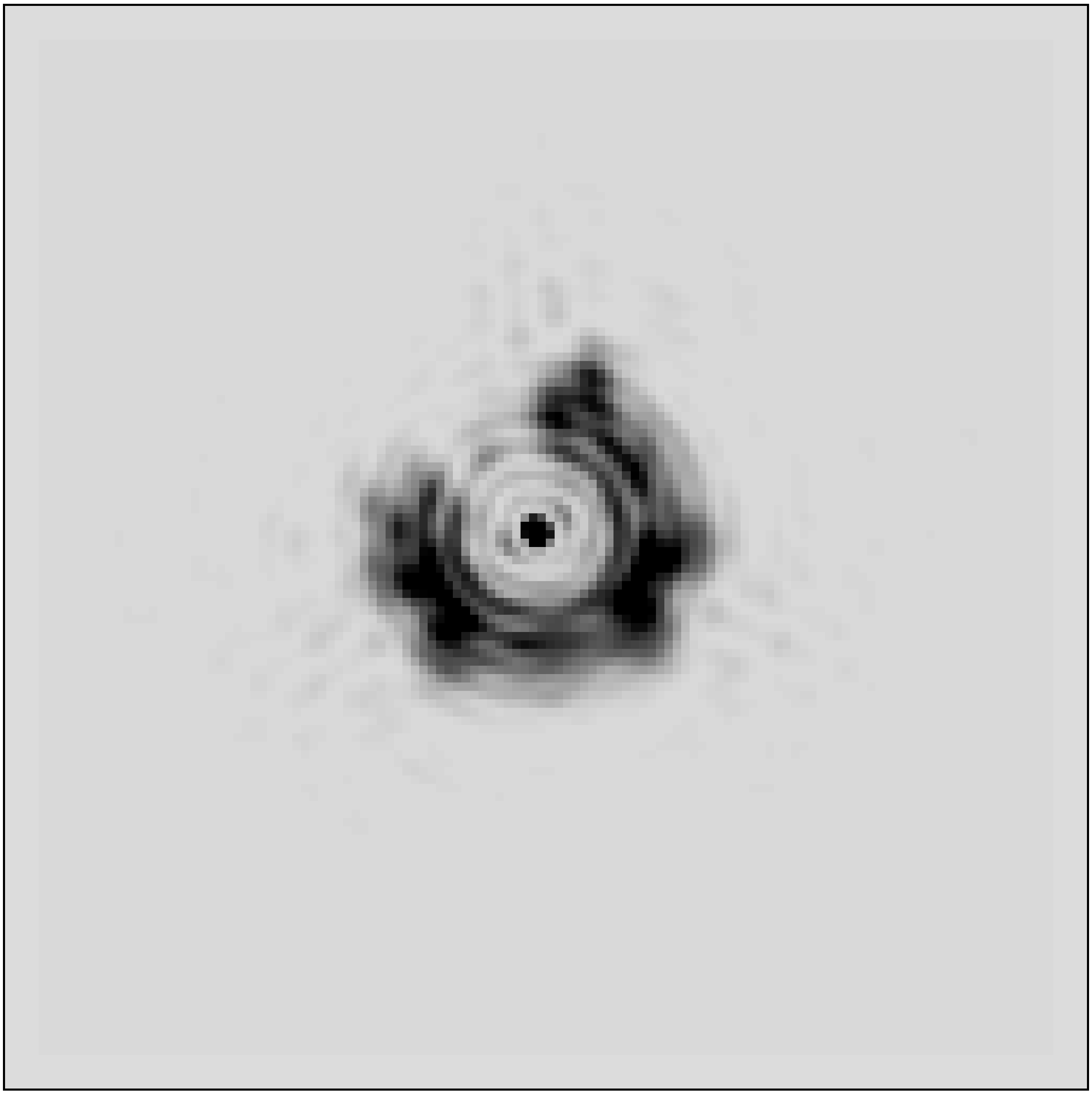


Fig. 8.— MACOS image of an on-axis monochromatic stellar source at 0.08 CCD-pixel scale

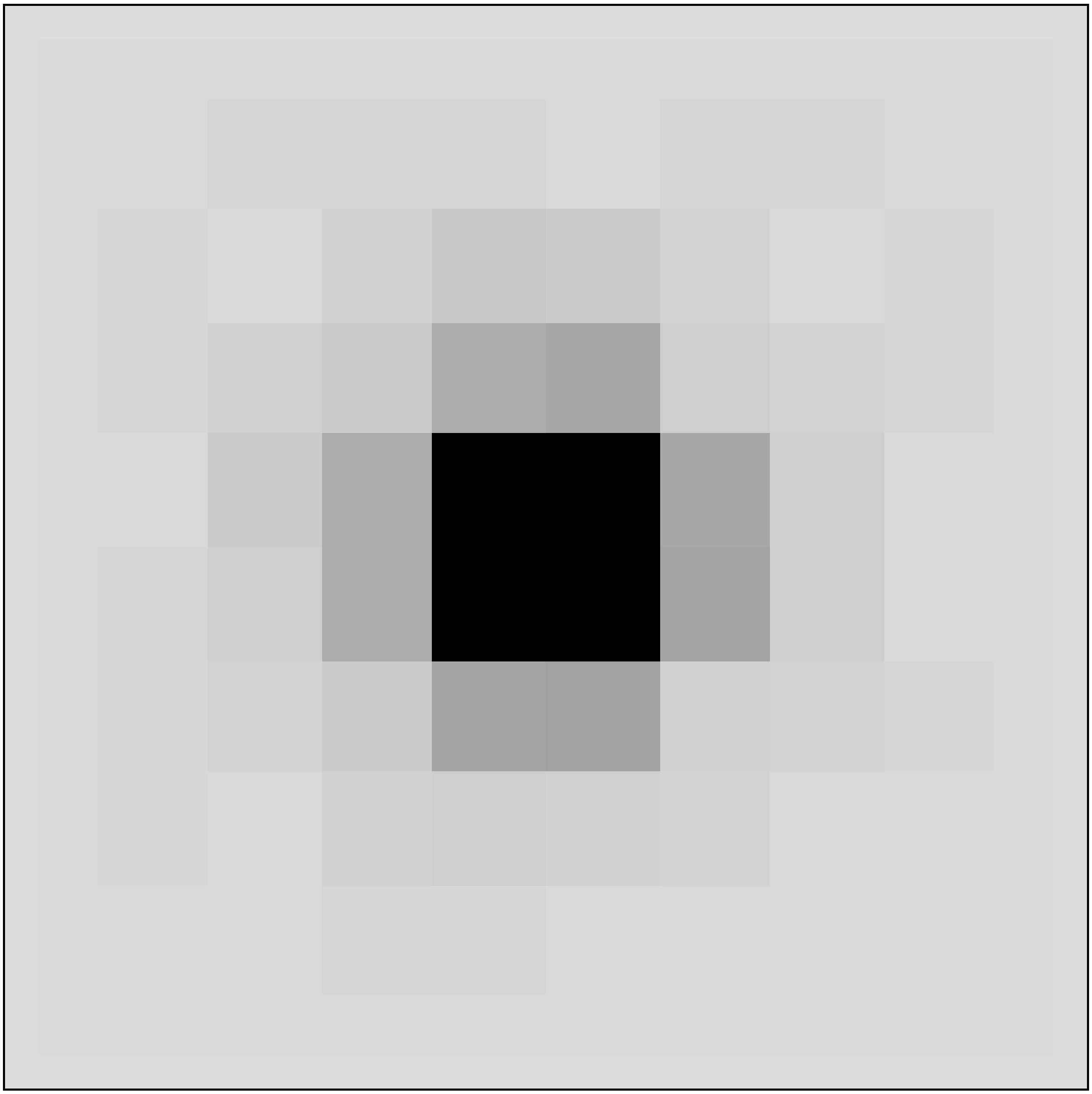


Fig. 9.— MACOS image of an on-axis fiducial light on a CCD-pixel scale

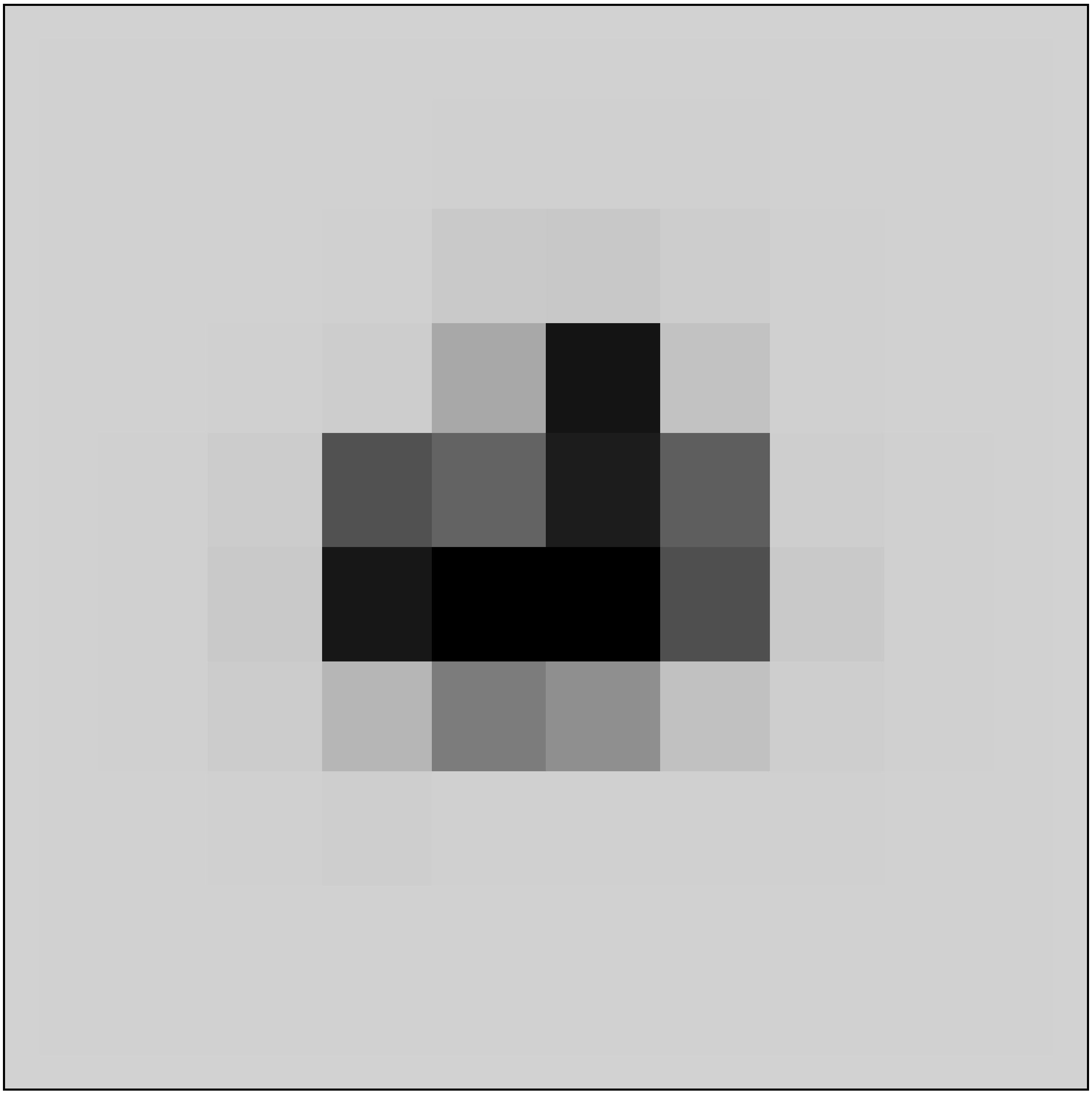


Fig. 10.— MACOS image of an on-axis guide star on a CCD-pixel scale

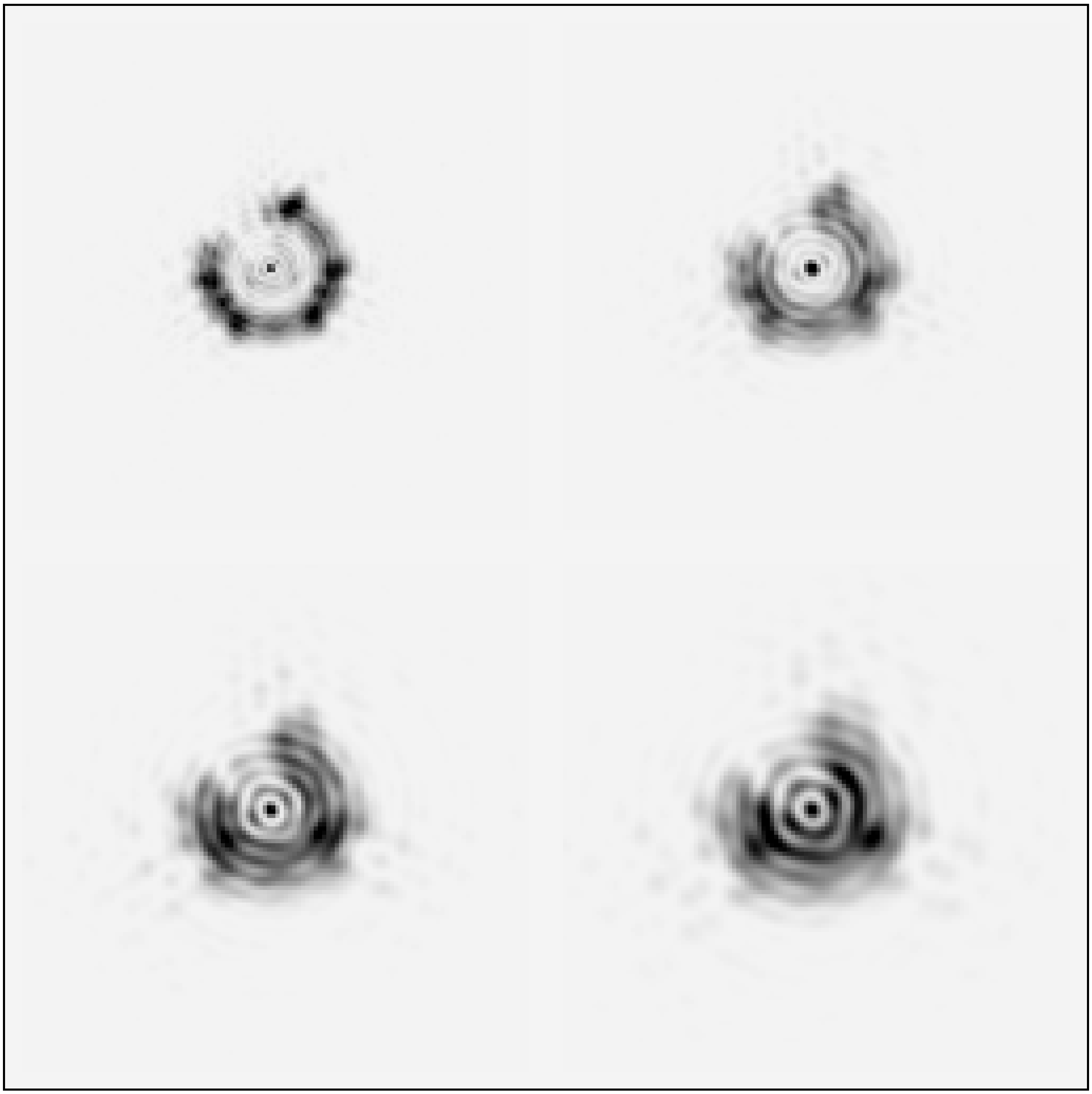


Fig. 11.— MACOS images of an on-axis monochromatic source on 0.08 CCD-pixel scale. Shown clockwise starting from the top left are the images at 400, 650, 800 nm, and 1000 nm

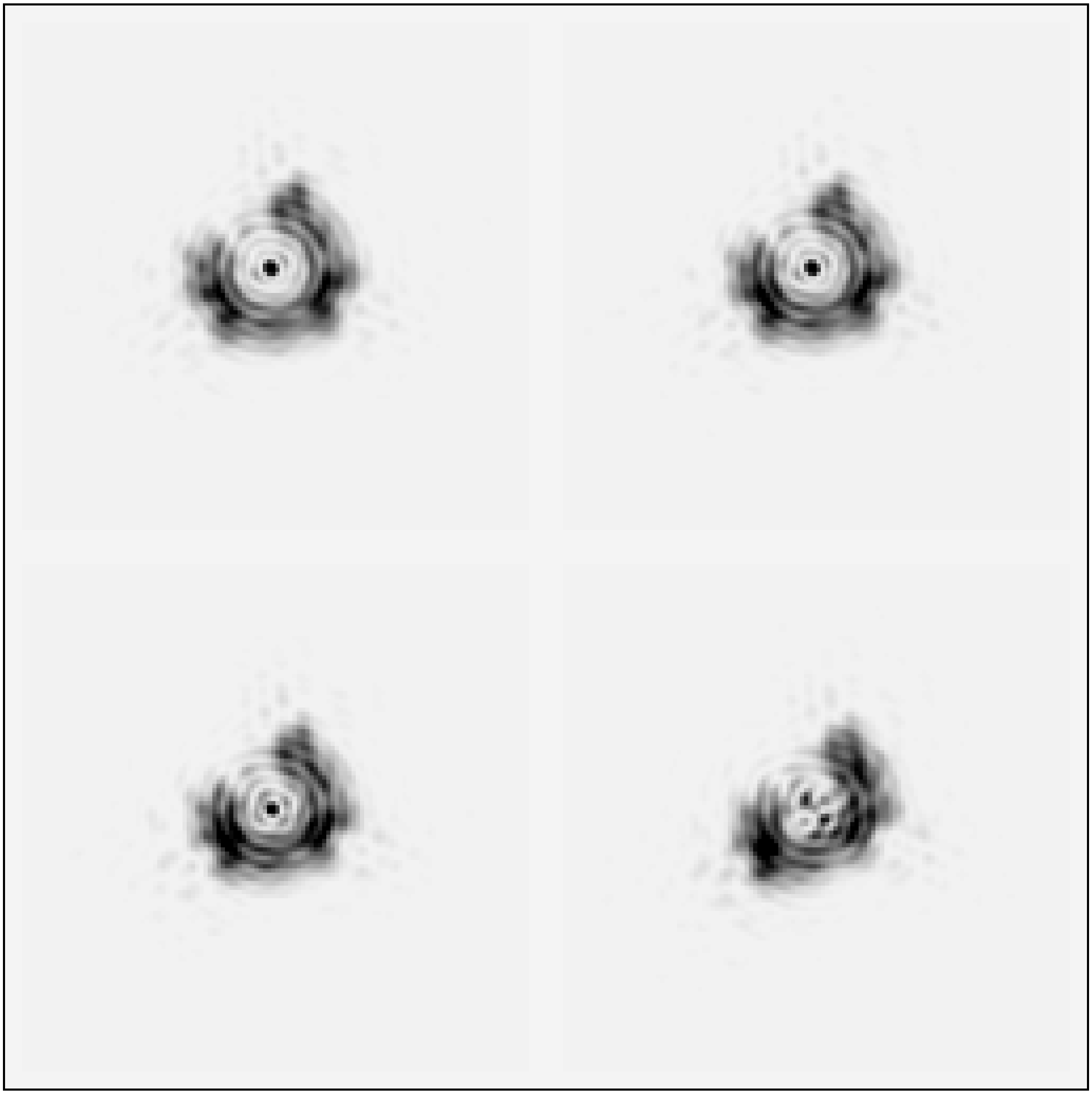


Fig. 12.— MACOS images of monochromatic on-axis and off-axis stellar sources. Shown clockwise starting from the top left are images in the CCD center, and at 15', 30', and 45' (pixelated on 0.08 CCD-pixel scale)

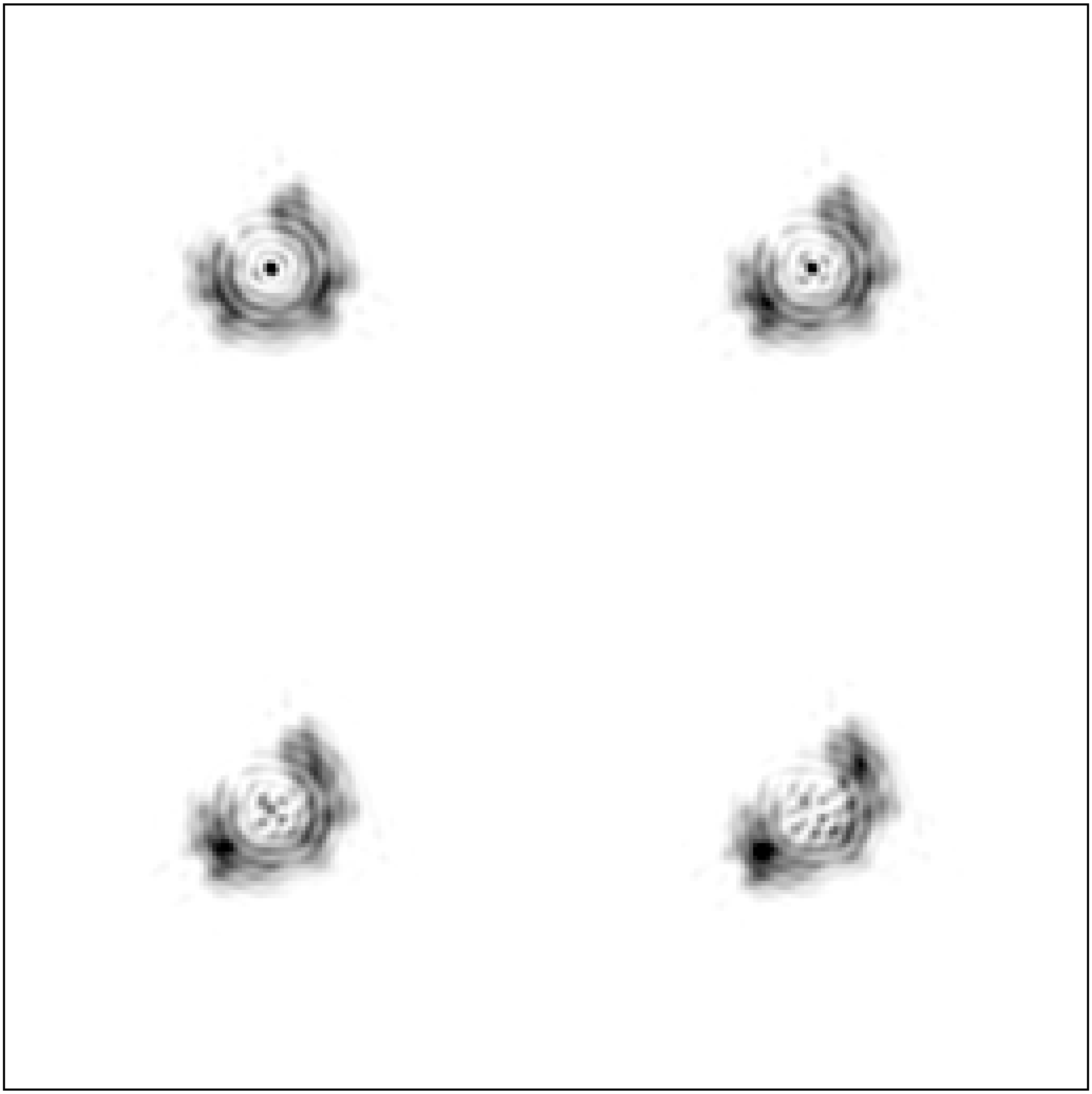


Fig. 13.— Comparison MACOS images of an on-axis monochromatic source on a 0.08 CCD-pixel scale with no astigmatism in the primary mirror and with increasing astigmatism at 45 degrees angle. Starting from the top left, going clockwise: image with no astigmatism, and images with 1/20 wave, 1/15 wave, and 1/10 wave astigmatism